Information Technology for the Twenty-First Century (IT^2)

Information Technology for the 21st Century
IT^2

- **Multi-agency presidential initiative**
- **Responds to findings of President's Information Technology Advisory Committee (PITAC)**
- **IT^2 increases Federal investments in:**
  - **Fundamental IT research**
  - Advanced computing for science and engineering
  - Ethical, social, economic, and workforce implications of IT

IT^2: Proposed FY2000 Budget

Agency	Fundamental Information Technology Research	Advanced Computing for Science, Engineering, and the Nation	Ethical, Legal, and Social Implications and Workforce Programs	Total
DOD	$100M	---	---	$100M
DOE	$ 6M	$ 62M	$ 2M	$ 70M
NASA	$ 18M	$ 19M	$ 1M	$ 38M
NIH	$ 2M	$ 2M	$ 2M	$ 6M
NOAA	$ 2M	$ 4M	---	$ 6M
NSF	$100M	$ 36M	$ 10M	$146M
Total	**$228M**	**$123M**	**$ 15M**	**$366M**

Fundamental IT Research

- **Long-term high-risk investigations of key issues in computer science and engineering**

- **Research focal points:**
  - **Software**
  - Human computer interfaces and information management
  - **Scalable information infrastructure**
  - High-end computing

DARPA

Fundamental IT Research

Software

- **Highest IT R&D priority according to PITAC**
  - The demand for software exceeds our ability to produce it
  - Today's software is fragile, unreliable, and difficult to design, test, maintain, and upgrade
- **Proposed research areas:**
  - Software engineering
  - End-user programming
  - Component-based software development
  - **Active software**
  - **Autonomous software**
  - **High-assurance software**

Fundamental IT Research

Human Computer Interaction And Information Management

- **Research to improve the ways we interact with computers**
  - Computers are still too hard to use; surveys show that computer users waste over 12 percent of their time because they can’t understand what their computers are doing
  - Improved accessibility for people without a keyboard (for example, mobile professionals and doctors) and persons with disabilities
  - Better techniques for locating data and extracting “knowledge” from data
- **Proposed research areas:**
  - Computers that speak, listen, and understand human language
  - Information visualization

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Fundamental IT Research

Scalable Information Infrastructure

- **Research to support the phenomenal growth of the Internet**
  - In 1985 the Internet connected 2,000 computers
  - Today it connects over 37 million computers
  - Future networks will connect at least a billion users and will be more complex – they will connect sensors, wireless modems, and embedded devices

- **Proposed research areas:**
  - **Deeply networked systems**
  - **Anytime, anywhere connectivity**
  - **Network modeling and simulation**

Fundamental IT Research

High-End Computing

- **Leading-edge research for future generations of computing to:**
  - Improve computational speed on applications
  - Increase the efficiency of massively parallel systems, with a focus on systems software
  - Develop technologies to enable future systems capable of a thousand trillion (10^{15}) calculations per second
- **Proposed research areas:**
  - Improved supercomputer performance and efficiency
  - Creation of a computational grid
  - Revolutionary computing

Advanced Computing For Science, Engineering, And The Nation

- IT^2 will obtain computers that are 100 to 1,000 times more powerful than those now available to the civilian research community, and make them available on a competitive basis
- Develop scientific and engineering simulation software and tools to make these computing systems useful research tools
- Establish and fund multidisciplinary teams working on most challenging problems

Economic And Social Implications Of It And It Workforce

- **Increased research in economic and social impacts will:**
  - Help in the design of information systems
  - Identify barriers to adopting IT and its applications
  - Provide more empirical data to policymakers
  - Encourage the solution of problems caused by IT
- **Proposed efforts in training IT workers at U.S. universities:**
  - Faculty access to modern curricula and instructional material
  - Graduate and post-graduate traineeships
  - University research grants through other components of this initiative will help support graduate students

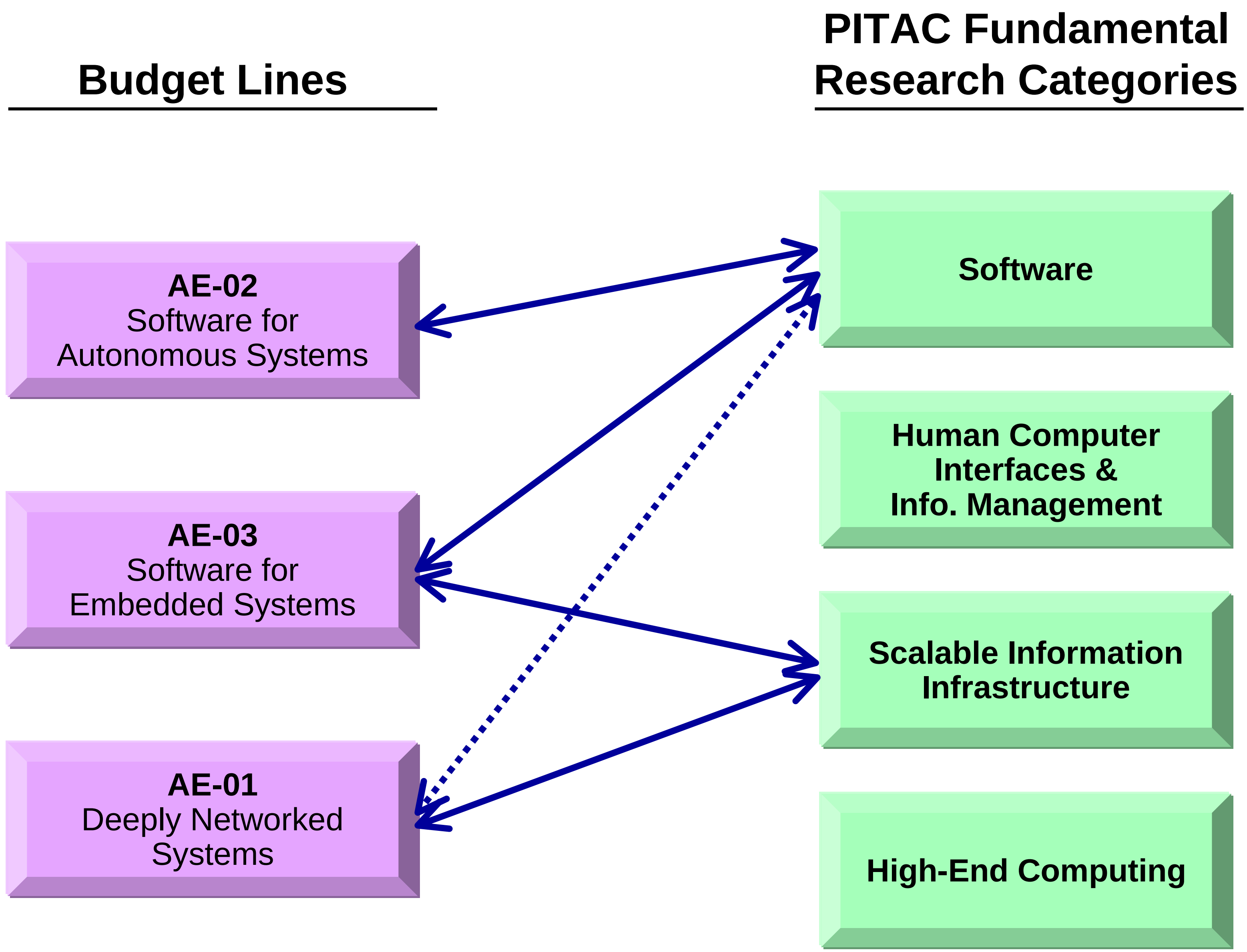
IT^2 Management

- **Policy and coordination committee of agency heads**
  - Help establish and monitor goals
  - Allocate research tasks
  - Ensure tight Federal coordination
  - Ensure open competitive allocation of funds
- **Working group reporting to the senior management team:**
  - Members appointed by principal agencies
  - Coordinate research in all major IT^2 areas
  - Ensure competitive selection processes are adopted

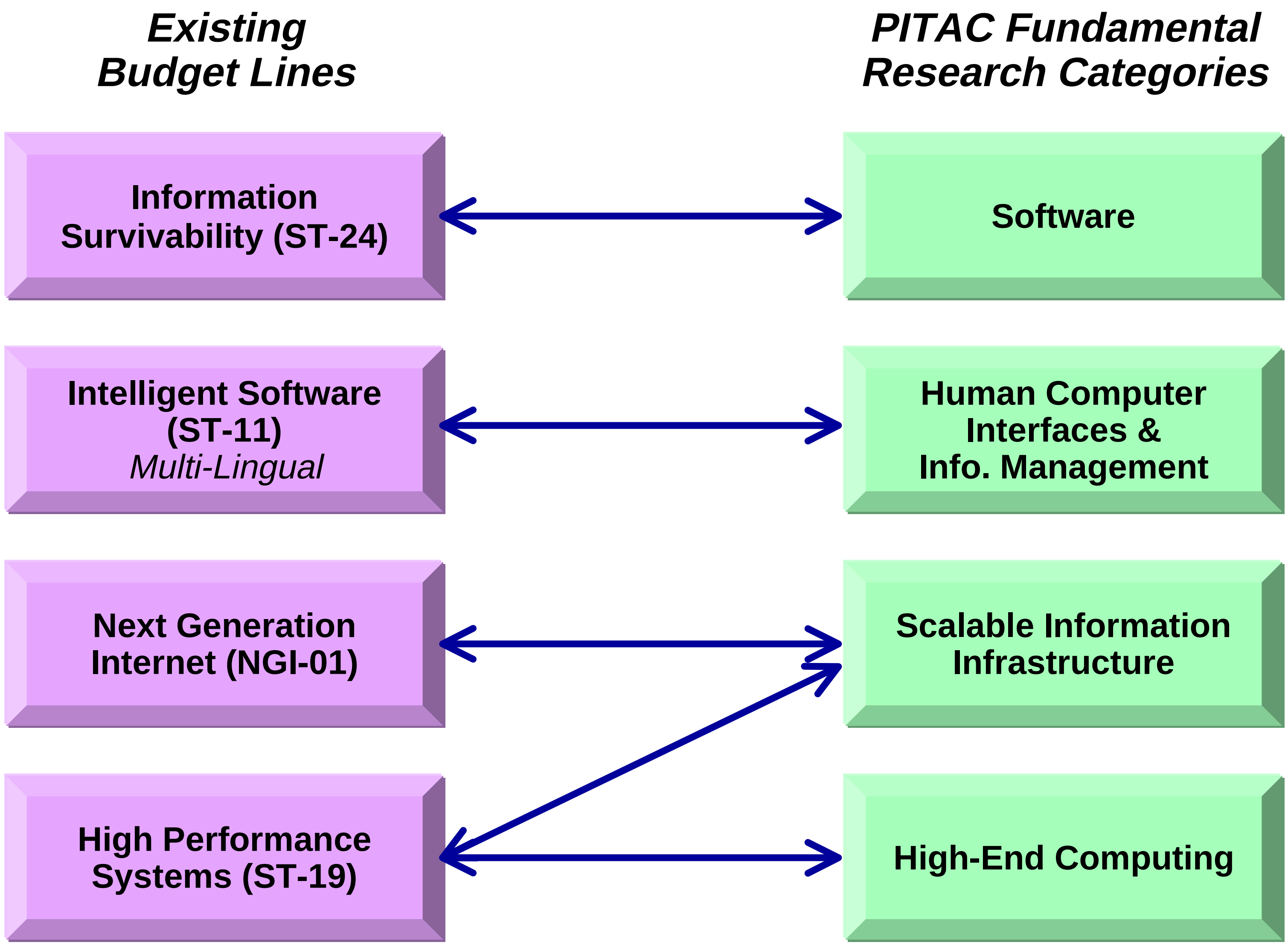
DoD Participation in IT^2

DARPA	$70M	• Software for Autonomous Embedded Systems • Deeply Networked Systems
ARDA (Intell. community)	$20M	• Part of $43M start-up • Secure Networks And Systems • Information Management Of Analysis And Presentation
DDRE (DUSD [S&T])	$10M	• University Research Initiatives (URI) • Young Investigator Awards

New DARPA Efforts Within IT^2



Existing DARPA Efforts Of Relevance To IT^2



Software For Autonomous Systems

Develop the missing software to enable pervasive employment of mobile autonomous robots

Program Goal

Autonomous:
Several robots/person
"unit commander"

Proposed Research

State-of-the-Art

Telesupervised:
One robot/person
"tank commander"

State-of-the-Practice

Teleoperation:
Several people/robot
"tank driver"

Limitations

- Vulnerability of wireless communications
- Performance degradation due to limited sensory feedback

Software For Autonomous Systems

- **Develop the missing software that will allow robots to perform on their own in the real world**
  - Software-enabled control that leverages computational capacity and memory to enable new modes of operation
  - High level software needed for adaptable, capable, easy-to-use, autonomous mobile robots
  - Network-enabled software for coordination of large numbers of autonomous systems
  - Uniform evaluation criteria to evaluate (and hence facilitate) improvement of the robot's intelligence quotient

Examples

Countermine, Urban Operations, Search & Rescue, Firefighting

Leverage the phenomenal progress made in mechatronics and information sciences to instantiate this capability

Representative Activity

Mobile Autonomous Robot Software

The Problem?

- Robots must be adaptable, yet remain goal-directed and predictable.
- Sensors are noisy, so robots must accommodate imprecise / incorrect data.

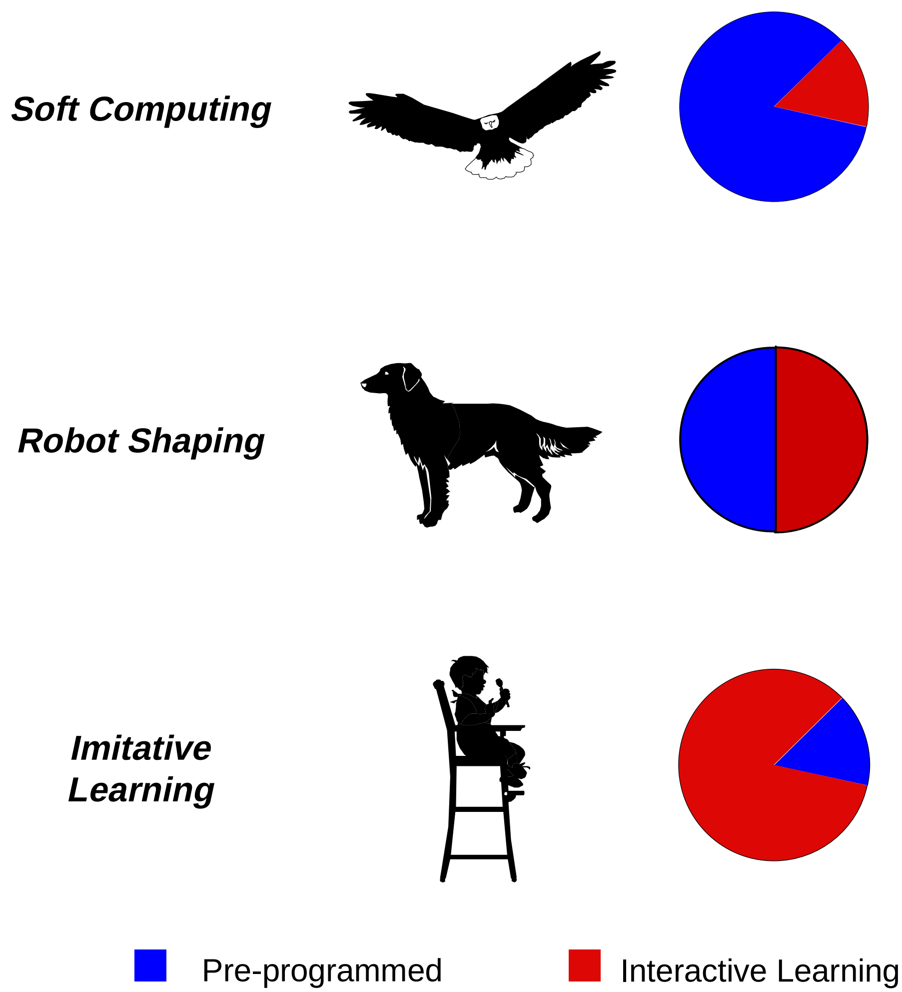
Why now?

- Progress in mechatronics and learning.

How?

- Synthesize deliberative (symbolic) and reactive (sensor mediated) methodologies.

Competing Approaches Differ wrt (Explicit) Programming / Learning Tradeoffs.



Representative Activity

Software For Distributed Robotics

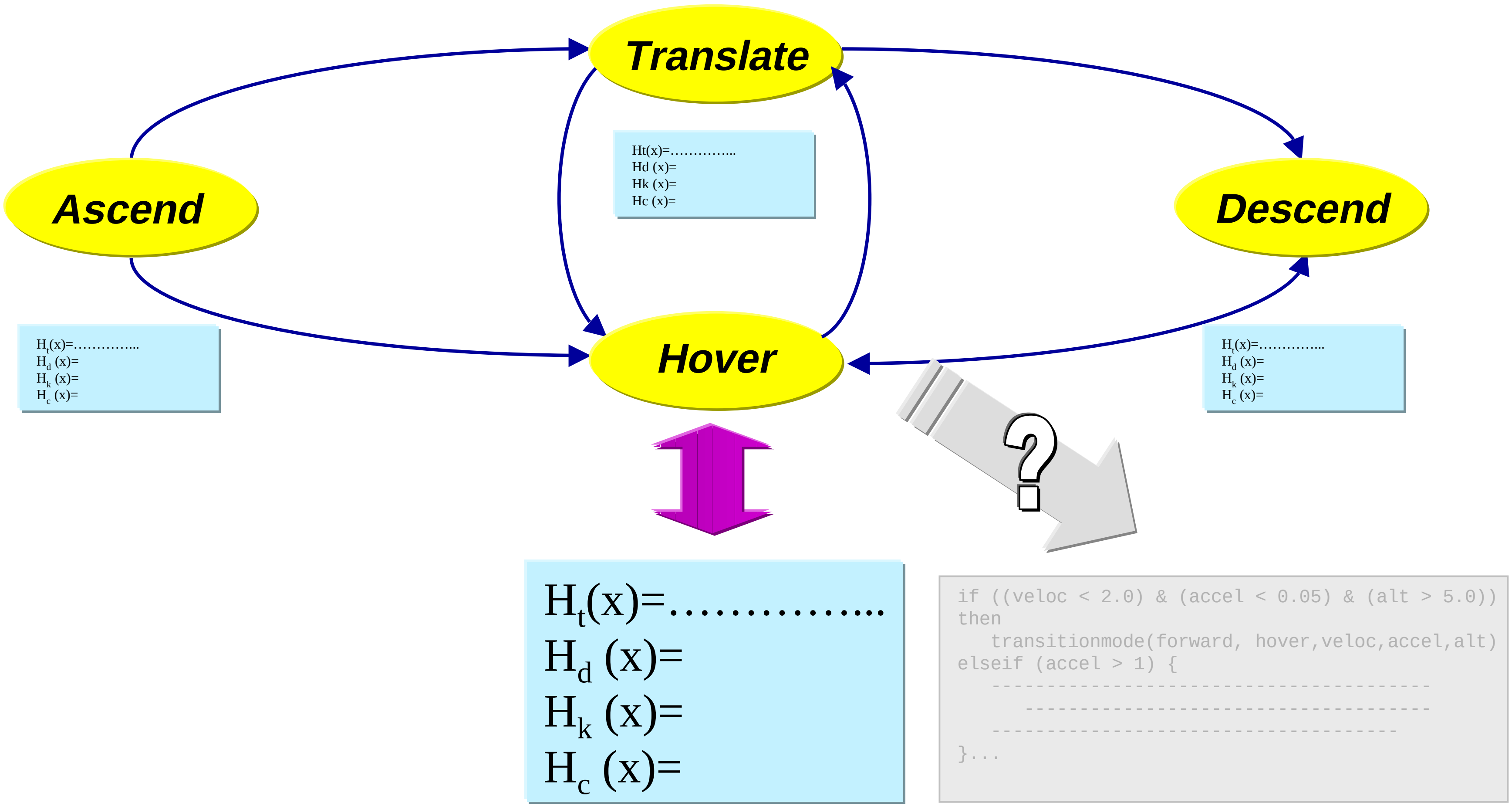
Large Scale Results From Many Small Scale Robots

- Unmanned aircraft and small robots offer an opportunity to exploit economies of scale if one can get them to work cooperatively.
- However, the limitations imposed on these comparatively small, networked devices have significant implications for the **software** including:
  - highly coordinated control for many small scale robots to accomplish a large scale task
  - resource constraints preclude using conventional implementations of network protocols
  - resource constraints limit processing available on-board the robots

Alternative Approaches

Distributed | **Mixed / Hybrid** | **Proxy**

Software-Enabled Control



Today: Static control laws; small number of modes; clumsy transition

Future: *Dynamic adaptation; many nano-modes; smooth transition*

Software-Enabled Control

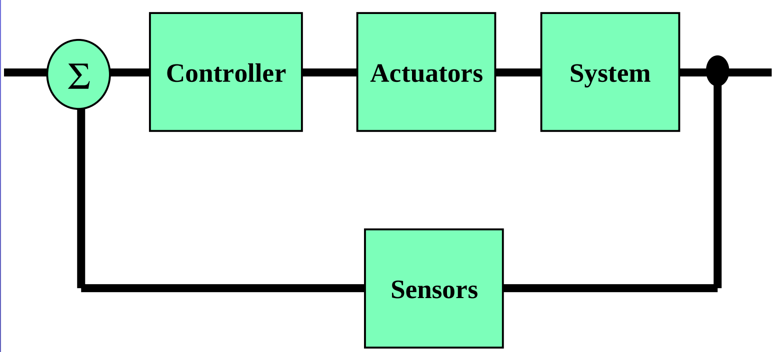
TODAY	*FUTURE*
Old assumptions: • limited processing power • limited data storage • fixed-loop implementation	**New assumptions:** • immense embedded processing power • multi-gigabit DRAM • powerful real-time software
Slow mode change	**Fast, predictive mode change**
Limited nodes/states	**Nano-states**
Static, fixed-frequency	**Dynamic control scheduling**
Fixed sensing/actuator resources	**Dynamic sensor & actuator allocation**
Closed control models	**Open, composable control**

Software-Enabled Control
Dynamic Control Scheduling

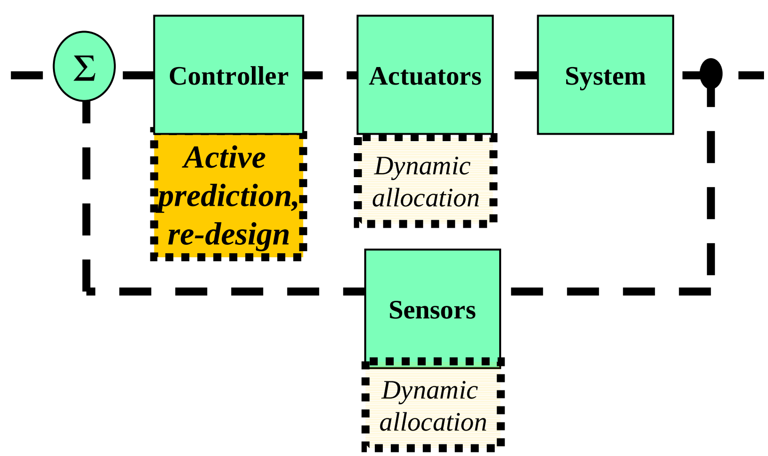
Change from fixed-loop control to modifiable control schedules that permit sensing and actuation actions and frequency patterns to be changed dynamically.

- This also permits idling sensors and actuators to be reallocated to other control tasks. (e.g., sensor released during chattering actuation; or one actuator substituted for another).
- Control actions can be dynamically scheduled.
- Irregular patterns and interleaved cyclic frequencies become possible. This enables sequencing of control actions that occur at different rates or that occur sporadically.

Fixed (rate-based) control loop

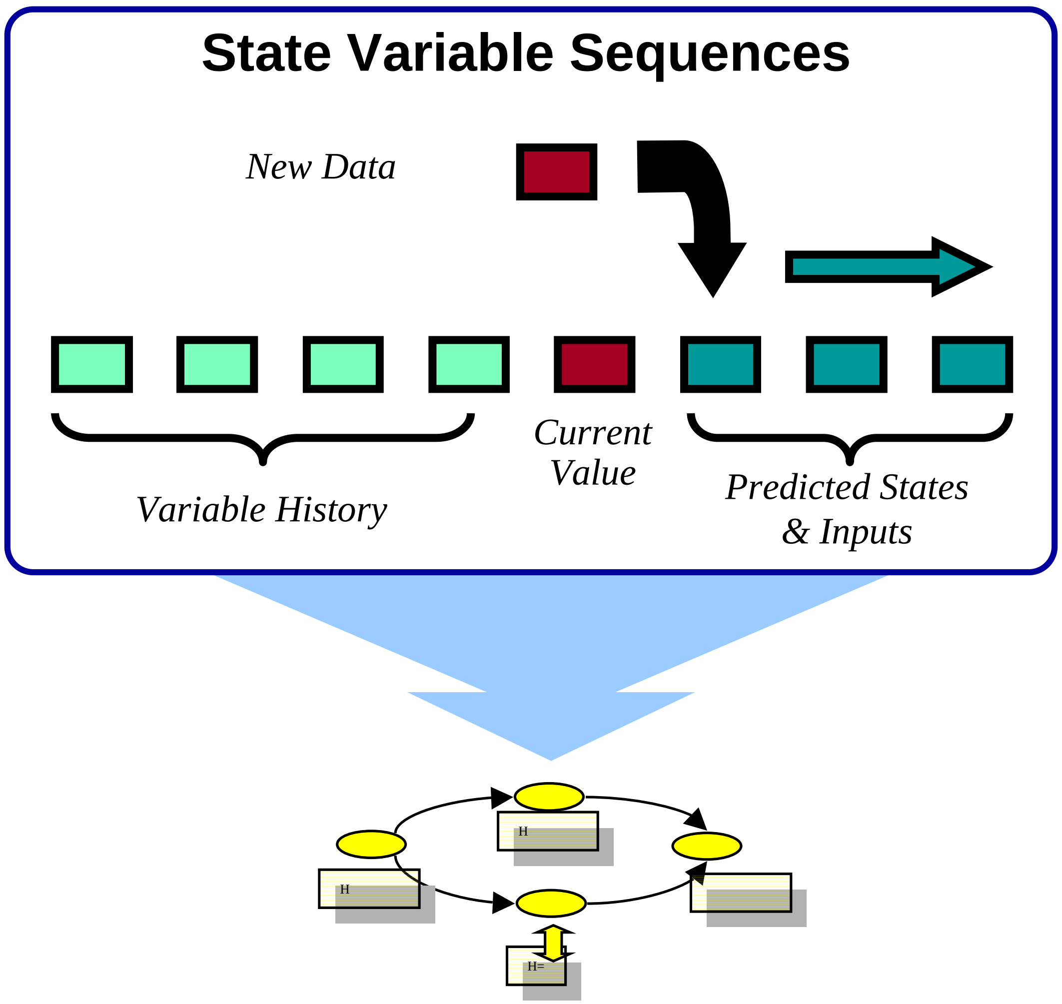


Open control (sensing, actuation) schedule



Active State Models
… With Predictive Transition

Active State Models = State Data + Faster-Than-Realtime Prediction



Agent-Based Negotiation

Leverage mobile code (agents) to achieve autonomous negotiation of large scale, dynamic, distributed allocation problems.

- m targets/consumers (moving changing)
- n resources (moving changing)
- allocation good enough & soon enough
- (response faster than human time)

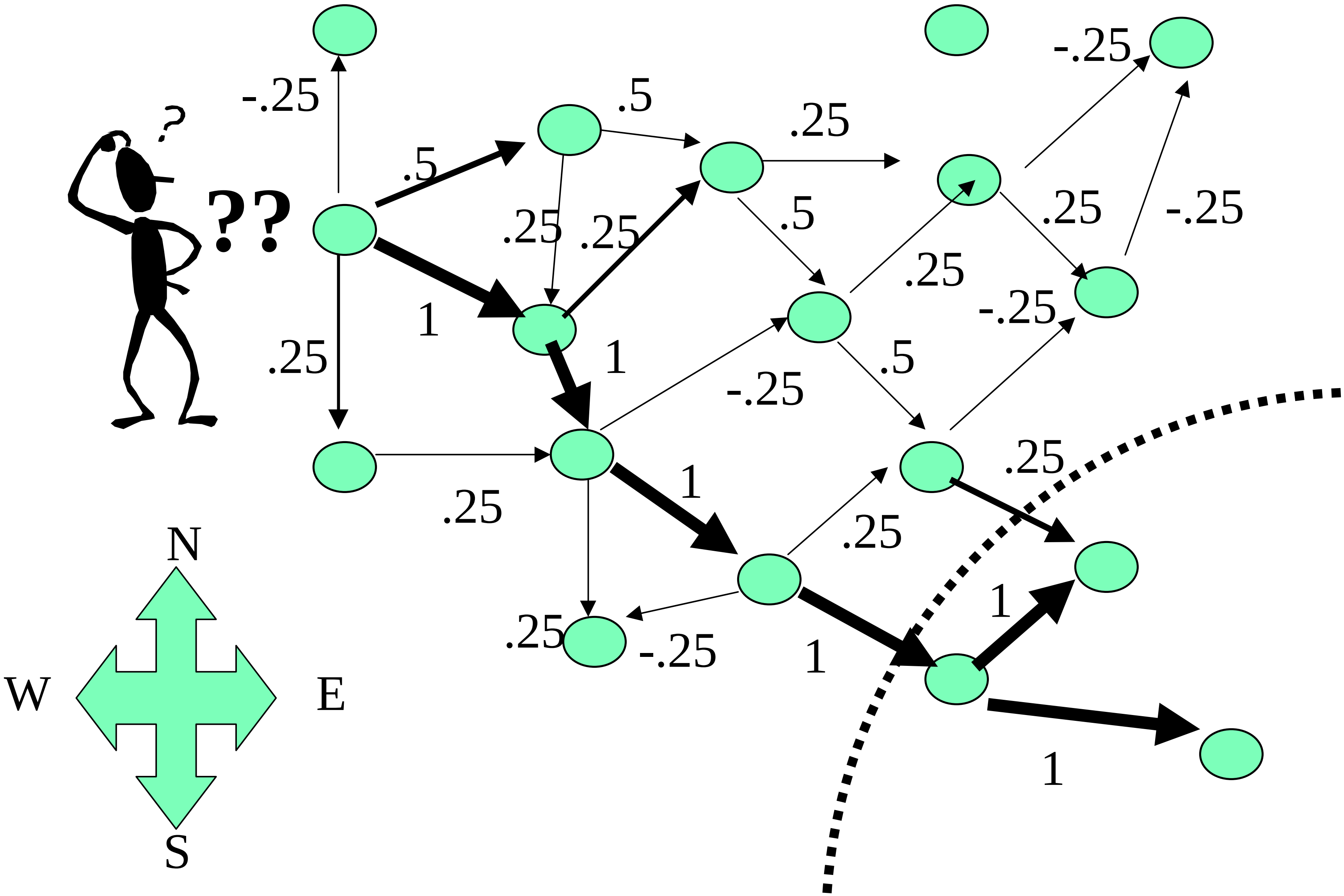
Software for Embedded Systems

Representative Activity: Sensor Networks

- **There are numerous sensor applications**
  - Surveillance of remote areas
  - Perimeter defense
  - Global asset instrumentation
- **However, software and networking technology to bridge the gap between sensors and useful systems is missing …**
  - **How do you enable "multi-tasking" of nodes and the network as a whole?**
  - **How do you "query" a sensor network?**
  - **How does information "flow" to the right places? How is it fused?**
- **SensIT will develop reusable Information Technology for Networked Sensor Projects**
  - Common software platform accelerates development
  - Powerful software algorithms

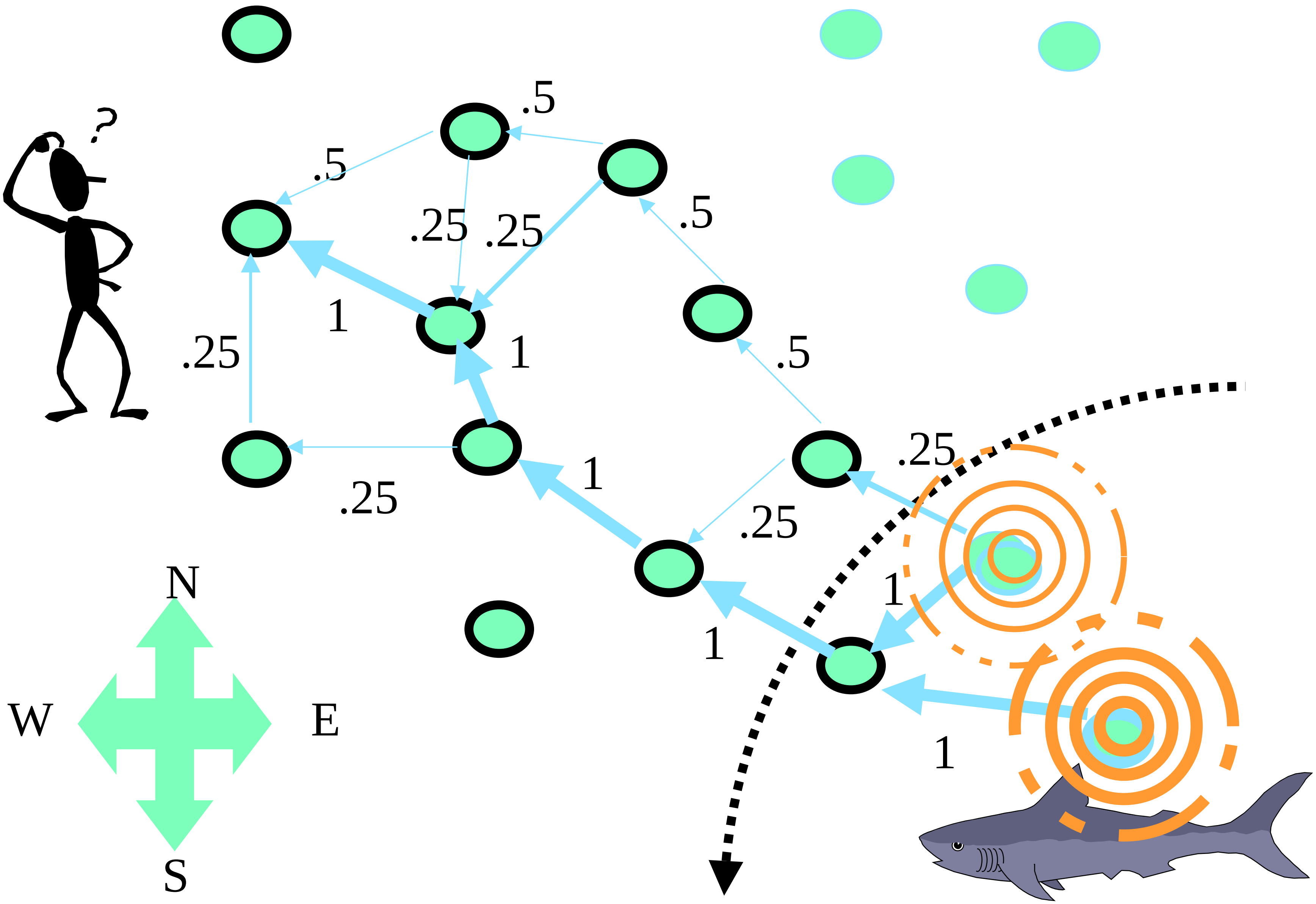
Tasking and Querying

Sample Approach: Information Gradients

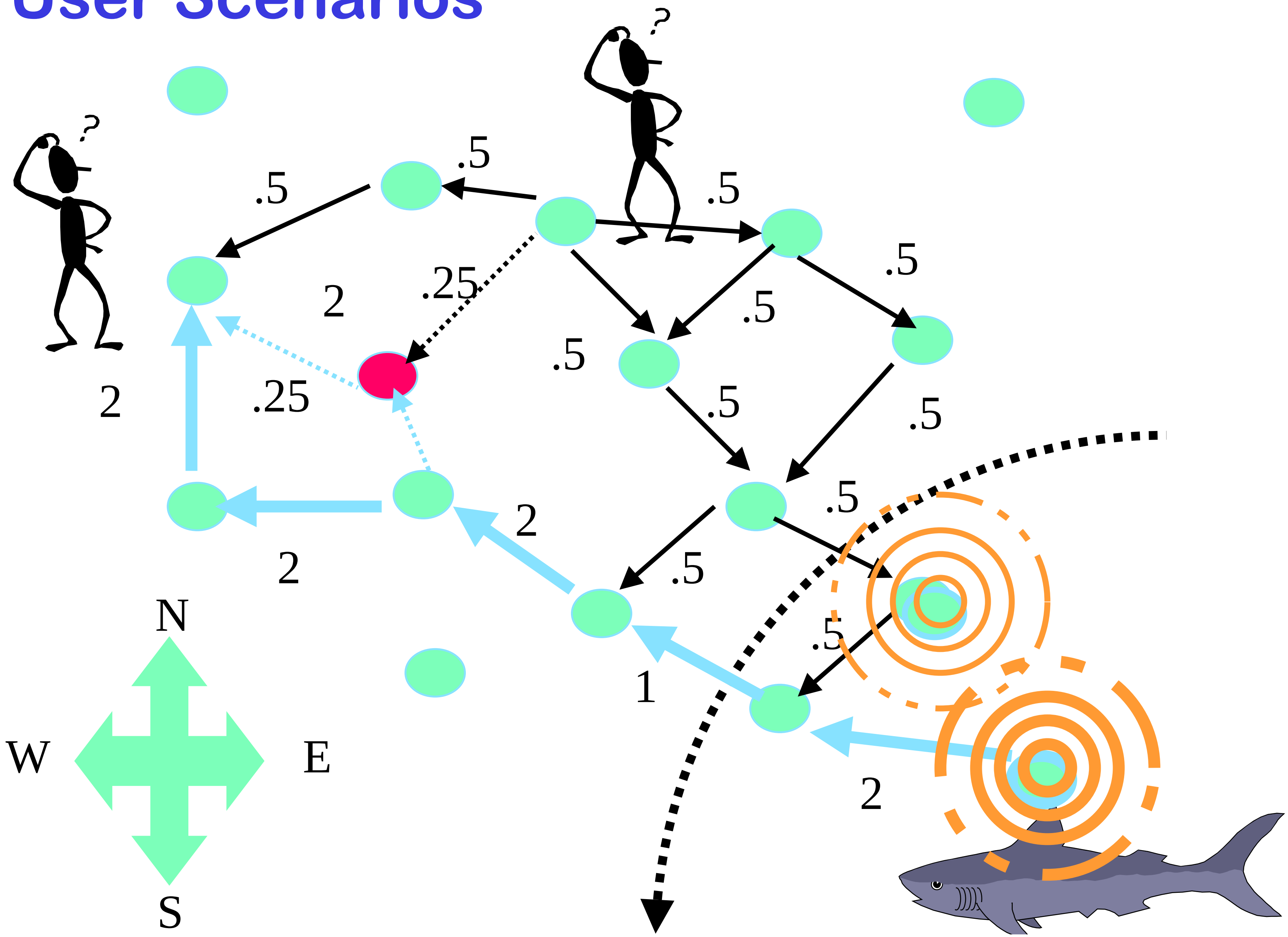


Tasking and Querying

Sample Approach: Information Gradients



Scales Well To Multi-Sink / User Scenarios

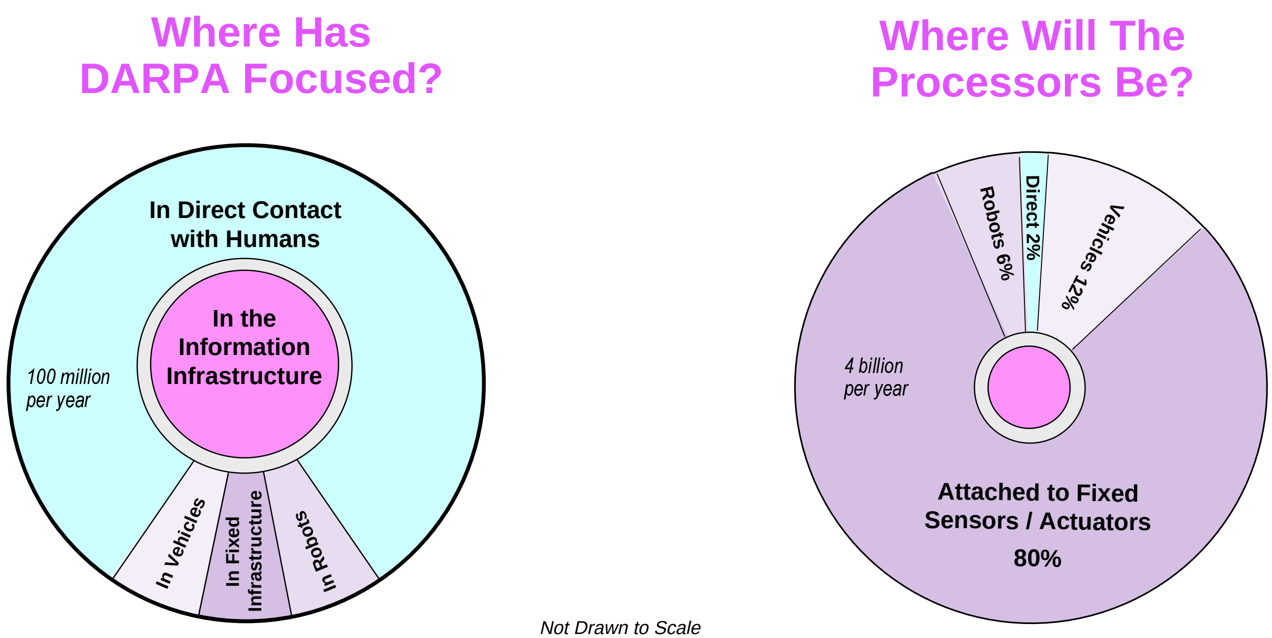


Software for Embedded Systems

Common Operating Environment

- **Software interface to communications, software GPS, sensors, “nanocryptography”**
- **Software for managing information flow in irregular networks of embedded devices**
- **Dynamic reprogramming interface**
- **Power Control**
  - Power budget is a first-class resource, driving activity schedule
  - Schedules wake-cycles and standby levels

Deeply Networked Systems



- Current Internet technology targets only 2% of all computers (PCs, servers, supers, etc.)
- The remaining 98% of computers are stranded within devices whose sensors and actuators are in direct contact with the physical world
- This project will extend the “depth” of the network to reach these embedded computational resources
- DARPA will conduct research on:
  - Multi-Modal Network Interfaces
  - Near Real-Time Networking
  - Agile Node & Network Services